EFFECTS OF CLOUD GEOMETRIC STRUCTURES
ON THEIR RADIATIVE PROPERTIES

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#N00014-95-1-1188

LONG TERM GOALS

The long term goals of this research are to improve our understanding of and ability to simulate the transfer of solar radiation in a medium consisting of heteorogeneous distributions of gases and aerosols.

OBJECTIVES

The objectives of this research are, through observations and modeling studies, to quantitatively evaluate the influence of heteorogenous distributions of the radiative properties of an atmospheric layer on solar radiance, both within and at the boundaries of the layer.

This work is supported by ONR Marine Meteorology program and with support for two graduate students through an AASERT award (#N00014-95-1-1188).

APPROACH

Develop methods to implicitly and explicitly simulate the transfer of solar radiation through heteorogeneous media.

Apply the above methods to deduce the sensitivity of the simulated radiances to the heteorogeneous characteristics of the media.

Seek simplified, alternative ways of describing the heteorogeneous characteristics of the medium for radiative transfer studies.

Devise techniques to observe the heterogeneous character of atmospheric layers.

Apply the above techniques to the characterization of the heteorogeneous nature of atmospheric layers.

WORK COMPLETED

Stochastic versions of the equations of Li and Ramaswamy's (1966) four stream spherical harmonic expansion approximation have been closed in a manner suggested by Gabriel and Evans (1996). In this first-order closure, the effect of layer inhomogeneity is to modify the solar source term in the radiative transfer equation and increase the domain-averaged intensity of the unscattered solar beam.

		Form Approved OMB No. 0704-0188

Report Documentation Page

1. REPORT DATE **30 SEP 1997**	2. REPORT TYPE	3. DATES COVERED **00-00-1997 to 00-00-1997**
4. TITLE AND SUBTITLE **Effects of Cloud Geometric Structures on Their Radiative Properties**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Colorado State University,Department of Atmospheric Science,Fort Collins,CO,80523**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Existing Monte Carlo models developed by the PI have been modified to include an exponential k-absorption scheme in order to more efficiently and accurately atmospheric extinction. This model is capable of explitely simulating the transfer of solar radiation in a heteorogeneous environment.

An eye-safe micro pulse lidar has been modified to a 30 meter resolution from its original 100 meter resolution; this increase in resolution makes it possible to resolve variations in the aerosol characteristics of boundary layer at the 30 meter scale.

RESULTS

In the case of conservative scattering, domain-averaged cloud albedo decreases with increasing variance of optical thickness (Figure 1), and there is a complementary increase in domain-averaged transmission. The variance of optical thickness also has an impact on the angular distribution of reflected radiance, increasing the anisotropy of reflection (Figure 2). This suggests that multiangle reflectance, in a single spectral band, may be the observation that will support estimates of the mean and variance of optical thickness.

The Monte Carlo model developed for the current effort incorporates an approximation of the spectral variation of absorption in the solar region, but treats accurately the effects of the spatial distribution of the cloud properties on its solar radiative budget. This type of model has been referred to in the past as an hybrid Monte Carlo model, Davis et al. (1981), and the current version couples a rather standard Monte Carlo scattering approach with a k-distribution parameterization in Stackhouse and Stephens (1986), for absorption by water vapor, carbon dioxide and oxygen. The vertical and/or horizontal radiative properties of the medium can be specified in terms of the volume extinction coefficient, an asymmetry parameter or phase function, a single particle scattering albedo and surface albedo and the mixing ratios of atmospheric H_2O, CO_2 and O_2. Initial model results indicate excellent agreement to plane parallel model results using the same absorption parameterization for clear and cloudy atmospheres.

The Enhanced Micro Pulse Lidar (EMPL) (Wood, 1997) features a user-programmable timing and control system by which the system resolution may be configured according to real-time research interests. Figure 3 illustrates to the sensitivity of the EMPL by clearly detecting the top of the boundary-layer aerosol and structure both below and above it.

IMPACT

There are several potential impacts of this research for both the field of atmospheric radiation and for the Navy. First, the characterization of complex, heterogeneous structures of radiatively active constitutents is a current problem in both theoretical and practical arenas. Just how much of the complexity must be retained in order to deduce reliable radiative transfer results is an open question. The complexity is so great that we must ascertain the minimum amount in order to have reliable results. This research seeks to establish a means of expressing this minimum.

The micro pulse lidar used in this research is an eye-safe system which operates at visible wavelengths; the conversion of the lidar to a resolution applicable in the boundary layer potentially makes available to the Navy a system which operates at the same wavelengths as many "smart" sensor systems and which can deduce the optical properties of the medium in an eye-safe manner. Data from this system will be invaluable in characterizing the radiative properties of the boundary layer for heteorogeneous paths.

TRANSITIONS

Planned in the future.

RELATED PROJECTS

ONR Project Entitled, "*Observational And Modeling Studies In Support Of The Atlantic Stratocumulus Transition Experiment (Astex)* " Contract #N00014-91-J-1422, P00007.

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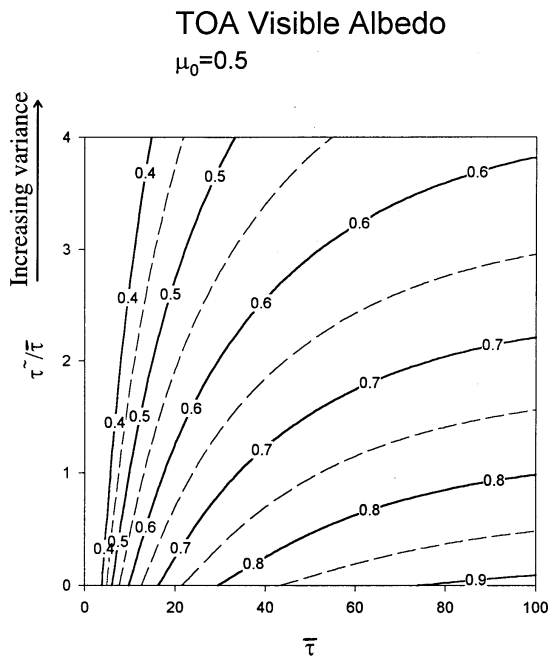
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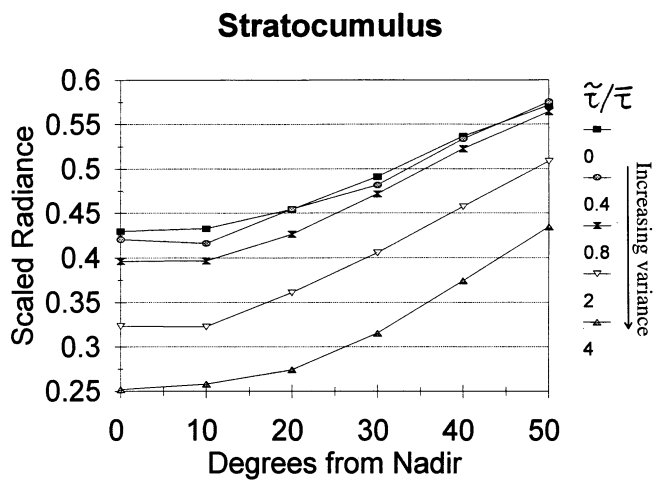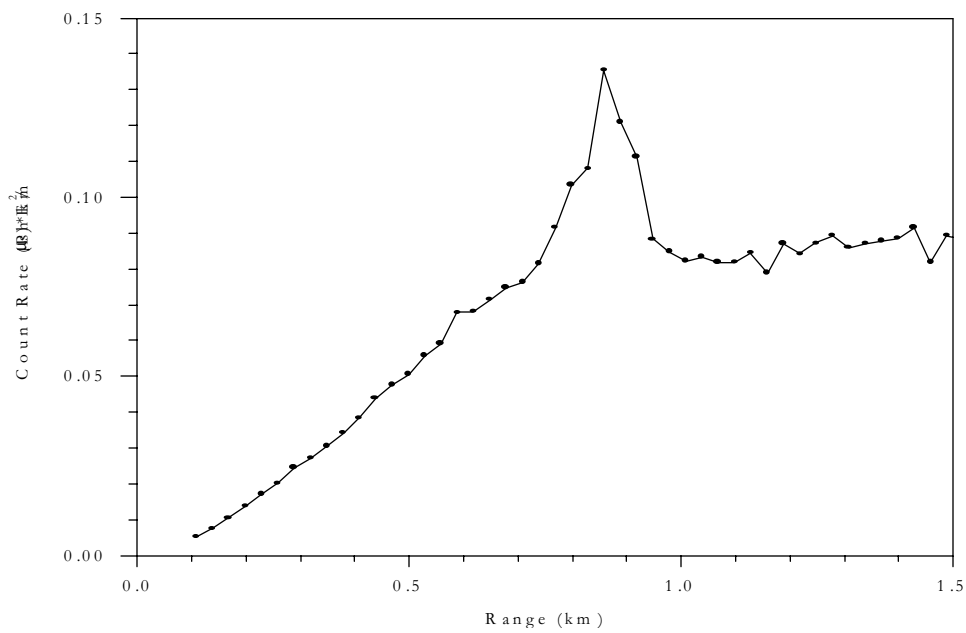$\mu_0=0.5$

Figure 1

Stratocumulus

Figure 2

Figure 3: Boundary-layer aerosol at 30 m resolution.